Efficiency and Welfare Impacts of Alternative Pricing Structures for Distributed Electricity Generation

Steven Sexton
Duke University
steven.sexton@duke.edu

Statement of Problem: Declining costs of variable renewable electricity technology and growing concern about air pollution from fossil generation contribute to policy enthusiasm for small-scale electricity generation distributed at load sites. The most common of these distributed generation (DG) technologies is rooftop solar photovoltaics (PV), the adoption of which is encouraged by a variety of local, state and federal incentives. Among these are net energy metering (NEM) policies that permit producers of DG to sell generation in excess of individual demand to utilities at retail rates charged by utilities. Because retail rates often exceed marginal costs of electricity supply due to utilities' revenue-raising constraints (rates exceed marginal cost) and regulators' distributional objectives (increasing block-rate pricing), NEM policies constitute generous subsidies to rooftop solar electricity generation. A subsidy to rooftop solar generation may be justified as second-best pollution control policy because it displaces polluting fossil generation. Advocates of DG also assert that it avoids transmission and distribution infrastructure costs and may render obsolete the traditional electric utility that procures and distributes electricity to retail customers. Economists, however, have suggested that existing NEM policies are too generous (e.g., Borenstein 2015).

Economists and representatives of utilities have also articulated the inequities introduced by NEM policies. As Borenstein and Davis (2015) note, rooftop solar and other clean technologies are taken up disproportionately by wealthy households. Thus, low-income households are less likely to receive the subsidies for rooftop solar capacity and generation. Moreover, because NEM customers are compensated at retail rates that incorporate cost recovery premia, high-income households can avoid costs of maintaining the electricity grid, even as they consume the grid as a virtual battery. They shift the burden of paying for the grid to low-income customers as utilities increase the cost recovery premia to account for the fewer electricity sales over which such costs are spread. Higher premia are expected to induce further rooftop solar adoptions, precipitating still further increases in rate premia that induce still additional solar adoptions in a positive feedback loop that increasingly shifts costs to low income households and could lead to the collapse of regulated utilities.

Even as prospects for DG have prompted New York state to formulate a new energy vision with wider deployment of DG renewables and California to embrace the power of "tens of thousands of tiny decisions" to adopt rooftop solar, the economics of distributed generation are not well understood. In particular, the merits of rooftop solar electricity generation relative to utility-scale or central plant solar generation are not obvious. Rooftop solar is assumed to avoid line losses and transportation and distribution costs, though utilities in California report that no such benefits have yet materialized in their operations (CPUC 2013). Even if such benefits are associated with solar DG, they accrue at the expense of forsaken scale economies and unexploited comparative advantage in solar electricity generation. Sexton and Rogers (2015), for

instance, find that the public cost per watt of rooftop solar generation in California exceeds the inclusive cost of utility-scale capacity and that suboptimal siting of the state's existing rooftop solar capacity forsakes at least 15% of possible generation.

Whether the marginal cost per unit DG delivered to load is less than the marginal cost per unit of central plant generation delivered to load is theoretically ambiguous and under-explored empirically. To the extent that renewable portfolio standards bind and DG is more costly than utility-scale solar generation, then generous subsidies to DG crowd out investment in more efficient utility-scale projects, contributing to perverse equity outcomes and higher electricity rates than are necessary to achieve renewable generation objectives.

Research Objectives and Methods: This proposal, therefore endeavors to:

1. **Assess the current costs and benefits of distributed variable renewable generation relative to utility-scale renewable generation and their likely evolution overtime; and to characterize the magnitude of efficient subsidies to DG.**

Though policy promoting DG is often motivated by interests in increasing VRE generation, renewable policy and DG policy are not synonymous. DG can be produced from non-renewable sources of generation, including diesel generators, and renewable generation can be supplied at load centers and at central plants away from load centers. And so pollution control can be achieved by promoting distributed VRE and central plant VRE. A priori, a policy preference for distributed VRE capacity relative to central plant VRE capacity is not obvious. Whereas the former is widely assumed to minimize costs of transmission and distribution, including line losses, the latter is able to exploit economies of scale and comparative advantage in siting the solar PV.

A first-best policy for DG would price a unit of supply according to time- and location-varying demand and the time and location-specific costs of moving electricity across the grid. Such variation in costs, however, is poorly understood by utilities, let alone by regulators (Black and Veach for CPUC). And Borenstein (2012) finds no evidence that existing DG capacity has avoided costs. DG capacity may, in fact, increase costs to the distribution system, while distribution system constraints may render incremental DG capacity in some locations of no value to the grid. Moreover, line losses from DG exports to the grid may rival the loss rate in transmission (Tabone and Callaway 2014). Finally, while the costs of solar PV systems have fallen dramatically, the gap in per unit costs between rooftop installations and utility-scale projects persists and has possibly increased overtime (Borenstein 2013).

While the costs and benefits of DG relative to central plant generation will vary according to variation in solar insolation within the interconnection and location-specific distribution and transmission infrastructure characteristics, a careful assessment of tradeoffs and their orders of magnitude is worthwhile and can be generated from existing research from government agencies, regulatory filings, and academic sources, including e.g., Borenstein 2015, Borenstein 2012, CPUC 2013, Mills and Wiser, 2010, and NREL 2010. This review of the literature will be used to characterize the magnitude of the optimal subsidy to DG.

2. **Estimate a revenue elasticity of rooftop solar adoption.**

If NEM provides too generous subsidies to rooftop solar, as economists and utilities claim, then they induce inefficient investments in rooftop solar on the extensive margin. (The marginal cost of rooftop solar generation is essentially nil.) The magnitude of this inefficiency can be characterized by estimating a revenue elasticity of adoption. This proposal will build upon existing work in Sexton and Rogers (2015) and ongoing collaboration with Bryan Bollinger and Ken Gillingham to estimate the magnitude of solar adoption attributable to subsidies. It will rely upon publicly available and confidential data on rooftop solar adoptions in California and implement a household adoption (logit) model using confidential data on household adoption decisions. An alternative specification follows Sexton and Rogers (2015) and is similar to Hughes and Podolefsky (2015) in that it relies upon publicly available daily counts of adoptions per zip code, as well as cost and other system characteristics.

3. **Estimate the quantity of additional rooftop solar capacity installed due to subsidies; and estimate distributional and efficiency implications of NEM policies and of other subsidies to rooftop solar.**

Equipped with an estimate of the responsiveness of solar adoptions to changes in NEM and other subsidies, the quantity of distributed solar capacity and consequent solar generation attributable to policy are estimated relying on modeled and observational data on system generation from the California Solar Initiative. Moreover, the magnitude of policy costs is estimated, as are impacts on electricity rates and cost shifting, assuming constant revenue constraints on utilities.

4. **Evaluate the efficiency and distributional implications of alternative policies for pricing renewable DG.**

As the efficiency and equity implications of NEM are better understood, regulators are considering alternatives that would mitigate cost shifting. A widely touted alternative is to combine NEM with a fixed access charge assessed to NEM customers. The fixed charge would compensate utilities for the grid services consumed by NEM customers. Such a policy would also deviate from first-best policy in that it would not charge customers the marginal cost of their grid services consumption. It would, however, likely improve efficiency and surely mitigate the perverse distributional impacts of NEM. A la Borenstein (2012) and Borenstein and Davis (2012), counterfactual rate policies will be simulated, relying on randomized, stratified samples of customer consumption profiles, Census Block Group or Census Block-level measures of household income, and solar generation profiles provided by modeled generation and observational records from the California Solar Initiative.

In addition to the NEM with fixed access charge, this project will also evaluate efficiency and equity impacts of tariffs that more accurately reflect the time and location-varying value of solar generation, as well as household consumption of grid services, which depends upon the customer demand and solar generation profiles. In particular, this project will also consider rates equal to (1) real-time wholesale pricing plus a pollution-avoidance premium, (2) feed-in-tariff rates paid

to large-scale renewable generators, (3) retail pricing with varying fixed connection charges, and (4) retail or wholesale pricing with a charge per unit of exports and imports from the grid.

5. Assess the magnitude of utility-scale crowd out under various DG pricing regimes.

So long as renewable portfolio standards bind, a unit of DG solar capacity crowds out a unit of utility-scale VRE capacity. Therefore, for various tariff regimes, including existing NEM, tariff induced DG capacity investments crowd out utility-scale capacity. This crowding-out effect can be estimated for each of the policies discussed under objective 4, using the revenue-elasticity-of-adoption estimates discussed in objective 2.

References

Borenstein, Severin. "Private Net Benefits of Residential Solar PV: The Role of Electricity Tariffs, Tax Incentives and Rebates." EI @ Haas Working Paper Number 259R, Energy Institute at Haas, 2015.

Borenstein, Severin. "The Redistributional Impact of Nonlinear Electricity Pricing." *American Economic Journal: Economic Policy* 4, no. 3 (2012): 56-90.

Borenstein, Severin. "The California Solar Initiative is ending. What has it left behind?" Energy at Haas blog, 2013. Accessed online November 2015: https://energyathaas.wordpress.com/2013/06/17/the-california-solar-initiative-is-ending-what-has-it-left-behind.

Borenstein, Severin. "The Private and Public Economics of Renewable Electricity Generation." *The Journal of Economic Perspectives* 26, no. 1 (2012): 67.

Borenstein, Severin, and Lucas W. Davis. "The Distributional Effects of US Clean Energy Tax Credits." In *Tax Policy and the Economy, Volume 30*. University of Chicago Press, 2015.

Borenstein, Severin, and Lucas W. Davis. "The Equity and Efficiency of Two-Part Tariffs in US Natural Gas Markets." *Journal of Law and Economics* 55, no. 1 (2012): 75-128.

Callaway, Duncan, Meredith Fowlie and Gavin McCormack. "Location, Location, Location: The Variable Value of Renewable Energy and Demand-side Efficiency Resources." EI @ Hass Working Paper 264, Energy Institute at Haas, 2015.

CPUC, California Public Utilities Commission. Biennial Report on Impacts of Distributed Generation. California Public Utilities Commission: Sacramento, CA, 2013.

Hughes, Jonathan E., and Molly Podolefsky. "Getting Green with Solar Subsidies: Evidence from the California Solar Initiative." *Journal of the Association of Environmental and Resource Economists* 2, no. 2 (2015): 235-275.

Mills, Andrew and Ryan Wiser. "Implications of Wide‐Area Geographic Diversity for Short‐Term Variability of Solar Power." Lawrence Berkeley National Laboratory: Berkeley, CA, 2010.

NREL, National Renewable Energy Labaratory. "How Do High Levels of Wind and Solar Impact the Grid? The Western Wind and Solar Integration Study." Technical Report, National Renewable Energy Laboratory: Golden, CO, 2010.

Rogers, Evan, and Steven Sexton. "Distributed Decisions The Efficiency of Policy for Rooftop Solar Adoption." American Economics Association Annual Meeting, Boston, 2015.

Tabone, Michaelangelo and Duncan Callaway. "Predicting the Regulation and Load Following Requirements of Distributed Photovolatics in California" (in preparation).